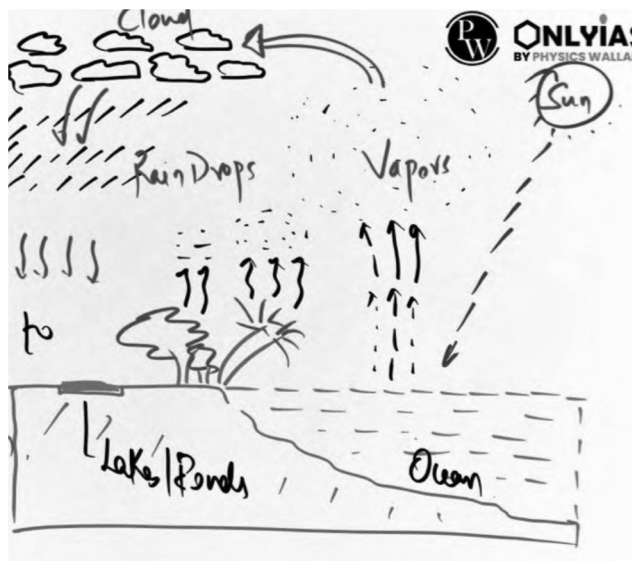


Environment

Lecture 05 : Functions of an Ecosystem (Part 03)

Nutrient Cycles:

- **Gaseous cycle :** It includes
 - Water cycle
 - Carbon cycle
 - Nitrogen cycle
 - Methane cycle
- **Sedimentary cycle:** It encompasses:
 - Phosphorus cycle
 - Sulphur cycle



Water Cycle:

- The water cycle is primarily driven by solar energy, which causes the movement of water between different reservoirs.
- Water can be stored in various forms, including oceans, soil, lakes, ponds, and the atmosphere.
- The movement of water between these reservoirs occurs through several processes: evaporation (water turning into vapor), transpiration (water released by plants), condensation (vapor cooling to form clouds), precipitation (water falling as rain, snow, etc.), and runoff (water flowing back to larger bodies like rivers and oceans).
- The cycling of nutrients is closely linked to the water cycle, as water is essential for transporting minerals and nutrients throughout the environment. Without water, the movement and availability of these essential elements would be greatly limited.

Carbon cycle:

- Carbon is a minor constituent in the atmosphere compared to oxygen and water.
- Carbon is vital in the form of carbon dioxide to perform photosynthesis for carbohydrates production for green plants.

- It involves an exchange between the atmosphere and organisms. **Typically considered a short-term cycle. Cycle steps include:**
 - Carbon is mainly in the form of carbon dioxide in the atmosphere.
 - Photosynthesis absorbs carbon into green plants and phytoplankton.
 - Respiration, excretion and decomposition return carbon to the atmosphere.
- **Some carbon enters a long-term cycle in marshy soil, aquatic sediments, or fossil fuels.**
 - Long-term carbon may take a long time to be released, such as in marshy soil or bottom sediments.
 - **In deep oceans**, carbon can remain buried for millions of years until geological movements expose rocks above sea level which are subjected to weathering and erosion and carbon is released back to the atmosphere.
 - Fossil fuels (coal, oil, natural gas) are organic compounds that were buried before getting decomposed and subjected to heat and pressure. Through geological processes, they transformed into fossil fuels. When burned, the stored carbon is released back into the atmosphere as carbon dioxide.

Nitrogen Cycle:

- Nitrogen is an essential constituent of protein and the basic building block of all the tissues.
- It is abundant in the atmosphere and available in the form of nitrogen gas and cannot be utilized directly. It is required to be converted into usable form. This process is called nitrogen fixation.
- There are different ways of nitrogen fixation:
 - By microorganisms like bacteria and algae
 - Industrial process like fertilizer production
 - By atmospheric phenomenon
- **Sources of Nitrogen:**
 - Lightning, volcanic eruption, ultraviolet radiation, industrial processes, forest fires, automobile exhausts, and thermal power-generating stations contribute to atmospheric nitrogen oxides (NO , NO_2 , N_2O).

- Animal waste like urea, uric acid, dead vegetation & organisms add nitrogen as nitrates directly into the soil.
- Burning coal releases CO, CO₂, sulphur dioxide and nitrogen oxides. Oxides of nitrogen fall on earth as smog and acid rain. Acidic rain is a complex mixture of nitrous, nitric, sulphurous, and sulfuric acids.
- Agriculture, through natural manure and legume crops, adds nitrogen to the soil.
- Urban waste such as vegetables, paper, and clothes contribute nitrogen.
- **Nitrogen Cycle Steps: Nitrogen Fixation → Nitrification → Ammonification → Denitrification.**
 - **Nitrogen Fixation:**
 - Nitrogen fixation is carried out by nitrogen-fixing microbes, industrial processes, and lightning.
 - **N₂-fixers:** Microbes with the enzyme nitrogenase convert atmospheric nitrogen into ammonia and ammonium ions. Examples include free-living soil bacteria (e.g., Azotobacter), symbiotic nitrogen-fixing bacteria (e.g., Rhizobium), and some cyanobacteria.
 - **Nitrification:**
 - Nitrification is the process by which nitrifying bacteria (e.g., Nitrobacter, Nitrosomonas) oxidize ammonia into nitrates.
 - **Ammonification:**
 - Ammonification is the conversion of waste products (urea, uric acid) into ammonium ions, which are then converted into nitrates. These nitrates are further converted into amino acids.
 - **Denitrification:**
 - Denitrification is the process in which nitrates are converted back into nitrogen gas, which is released into the atmosphere. This is carried out by bacteria such as Thiobacillus and Pseudomonas.

Methane Cycle

- Methane (CH₄) is a **more potent greenhouse gas (GHG) than carbon dioxide(CO₂)**.
- Despite its potency, methane has a **shorter atmospheric lifetime** than carbon dioxide.
- **Natural Sources of Methane:**

- **Wetlands:** Methanogens (prokaryotic archaea- bacteria) in hypoxic conditions produce methane during the decomposition of organic matter. Wetlands contribute to about 80% of global CH_4 emissions from natural sources.
- **Termites:** Microbes in guts of termites produce methane through anaerobic fermentation during digestion.
- **Oceans:** Methane sources from oceans include anaerobic digestion in marine zooplankton, fish, and methane produced in sediments/drainage areas.
- **Methane Hydrates:** Formed when hydrogen-hydrogen bonded water and methane gas come into contact at high pressures and low temperatures in oceans. Found in the form of crystalline ice, and also trapped in permafrost.
 - They are found at:
 - Under sedimentary rocks of Arctic
 - Sedimentary deposit of ocean shelf
 - Under Antarctic ice.
 - Sediments of ocean beds.
 - Ocean acidification, climate change, or any other anthropogenic disturbance can destabilise the methane hydrates and lead to the release of an immense amount of methane — can lead to mass extinction.
- **Human Sources of Methane Emissions:** Globally, 50–65% of total CH_4 emissions come from human activities, with significant contributions from: Agriculture (40%), Fossil Fuels (35%), Waste (20%). **Specific Human Sources:**
 - **Landfills:** Methane is generated in landfills as waste decomposes under anaerobic conditions.
 - **Wastewater Treatment:** Treatment processes produce methane if done without oxygen (anaerobic conditions).
 - **Fossil Fuels:** Released during production, storage, and transmission of natural gas. Methane trapped in coal deposits released during mining (Coalbed Methane).
 - **Livestock:** Domesticated livestock, such as cattle, produce methane during digestive processes.
 - **Rice Cultivation:** Flooded rice cultivation produces methane during the decomposition of organic matter.

- **Biomass Burning:** Incomplete burning of organic matter results in methane emission.
- **Human source > Natural Source**
- **Natural Source:** Wetlands > Termites > Oceans > Methane Hydrates
- **Human Source:** Agriculture > Fossil Fuels > Waste
- **Methane Sink:** Soils act as a major sink for atmospheric methane through methanotrophic bacteria that use methane in a process called Methane Oxidation.
- **Removal from Atmosphere:** Methane is removed from the atmosphere by reacting with the hydroxyl radical (OH), converting it to CO₂ and water vapor. Hydroxyl radicals (cleanser of the atmosphere) are a form of sink because they scrub the atmosphere clean of pollutant molecules and break them down.
- **Impact of Methane:** Contributes to the formation of ground-level ozone, a dangerous air pollutant. Methane hydrates can release a significant amount of methane with warming, contributing to climate change.

Sedimentary Cycles

Phosphorus Cycle

- The phosphorus cycle involves the movement of phosphates from rocks to rivers and oceans, then back to the Earth's crust through geological processes.
- Phosphorus mainly originates from phosphate rocks, which release phosphates through weathering and erosion.
- These phosphates are carried by runoff into rivers and oceans.
- In ocean beds, phosphates settle and accumulate, becoming deposited in deep beds or continental shelves, forming part of these rocks permanently.
- After millions of years, crustal plates move, lifting these deposits to the surface.
- The exposed deposits undergo weathering and erosion, and the phosphates are again carried to the sea and river beds, where accumulation and deposition occur once more.

Sulphur Cycle

- The sulphur cycle includes atmospheric input, deposition as acid rain, plant uptake, transfer through the food chain, and return to soil and water through excretion and decomposition.
- **Sources of Sulphur:** Sulphur is locked in organic (coal, oil, peat) and inorganic (pyrite rock, sulphur rock) soil deposits as sulphates, sulphides, and organic sulphur. Released by

weathering of rocks, erosional runoff, and decomposition of organic matter, it is carried to terrestrial and aquatic ecosystems in salt solutions.

- **Steps in the Sulphur Cycle**

- **Atmospheric Input:** Sulphur enters the atmosphere as sulphur dioxide from volcanic eruptions, combustion of fossil fuels, ocean surfaces (Dimethyl Sulfide - DMS), and gases released by decomposition. DMS is an organosulfur compound derived from marine algae, plants, and animals, serving as a primary source of marine sulphate aerosols.
- **Atmospheric Deposition:** Sulphur dioxide in the atmosphere is carried back to the earth as weak sulphuric acid (acid rain).
- **Plant Uptake:** Sulphates in the form of atmospheric deposition or other sources are taken up by plants. Incorporation into sulphur-bearing amino acids occurs through metabolic processes.
- **Food Chain Transfer:** Sulphur, incorporated into amino acids, passes through the grazing food chain.
- **Return to Soil and Water:** Sulphur bound in living organisms is returned to the soil, bottom of ponds, lakes, and seas through excretion and decomposition of dead organic material.

UPSC Prelims PYQ:

Q. Which of the following statements are correct about the deposits of 'methane hydrate'?

1. Global warming might trigger the release of methane gas from these deposits.
2. Large deposits of 'methane hydrate' are found in the Arctic Tundra and under the seafloor
3. Methane in the atmosphere oxidizes to carbon dioxide after a decade or two.

Select the correct answer using the code given below.

- (a) 1 and 2 only
- (b) 2 and 3 only
- (c) 1 and 3 only
- (d) 1, 2 and 3

Q. Which of the following are nitrogen-fixing plants?

1. Alfalfa
2. Amaranth



3. Chickpea
4. Clover
5. Purslane (Kulfa)
6. Spinach

Select the correct answer using the code given below:

- (a) 1, 3 and 4 only**
(b) 1, 3, 5 and 6 only
(c) 2, 4, 5 and 6 only
(d) 1, 2, 4, 5 and 6

Q. In which one of the following biogeochemical cycles, the weathering of rocks is the main source of release of nutrients to enter the cycle?

- (a) Carbon cycle
(b) Nitrogen cycle
(c) Phosphorus cycle
(d) Sulphur cycle